

VIRGINIA RECREATIONAL FISHING DEVELOPMENT FUND SUMMARY PROJECT APPLICATION*

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|---|--|----------------------|-----------|---------------------------|----------|---------------------|-----------|
| NAME AND ADDRESS OF APPLICANT: Virginia Institute of Marine Science P.O. Box 1346 Gloucester Point, VA 23062 | PROJECT LEADER (name, phone, e-mail): Andrij Z. Horodysky (andrij@vims.edu) (804) 684-7522 Dr. Robert Latour (latour@vims.edu) (804) 684-7312 | | | | | | |
| PRIORITY AREA OF CONCERN: Research | PROJECT LOCATION: Virginia Institute of Marine Science | | | | | | |
| DESCRIPTIVE TITLE OF PROJECT: Seasonal caloric needs and energy intake of Chesapeake Bay's predatory fishes: which prey fuel growth and reproduction? | | | | | | | |
| PROJECT SUMMARY: At present, little is known about the energy requirements of recreationally important sportfishes, which prey species contribute most to these energetic needs, and how these relationships change in time. This project will therefore assess the seasonal energy requirements of Chesapeake Bay sportfishes and the seasonal caloric values of their prey. These data, combined with dietary inferences from existing surveys, will allow the estimation of the seasonal energy consumption by striped bass, summer flounder, weakfish, spotted seatrout, and red drum. This approach will provide a better understanding of the relative contributions of various prey species to the maintenance and growth needs of recreationally-important predators in different seasons. | | | | | | | |
| EXPECTED BENEFITS: Few direct measurements of energy requirements exist for Chesapeake Bay's predatory fishes, and even fewer data are available on the caloric values of prey species. It is therefore unclear which prey species are most critical to fulfill the seasonal energy requirements and support growth and reproduction in our recreationally-important fishes. Such insights are critical first steps towards combining ecosystem level processes and population level inferences, ultimately improving models of predator-prey relationships with implications for fisheries management. These data will also benefit Virginia's recreational anglers by allowing a better understanding of the mechanisms underlying seasonal interactions of recreationally important sportfishes and their prey, with implications for bait/lure selection and fishing tactics. | | | | | | | |
| COSTS: <table border="1"><tr><td>VMRC Funding:</td><td>\$ 40,060</td></tr><tr><td>Recipient Funding:</td><td>\$ 6,185</td></tr><tr><td>Total Costs:</td><td>\$ 46,245</td></tr></table> Detailed budget must be included with proposal. | | VMRC Funding: | \$ 40,060 | Recipient Funding: | \$ 6,185 | Total Costs: | \$ 46,245 |
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SEASONAL CALORIC NEEDS AND ENERGY INTAKE OF CHESAPEAKE BAY'S PREDATORY FISHES: WHICH PREY FUEL GROWTH?

Anticipated budget – Horodysky and Latour

| | | MRFAB | VIMS | TOTAL |
|-----------------------------------|--------|---------------|--------------|------------------|
| Personnel | | | | |
| R. Latour | 1 mo. | 6,825 | | 6,825 |
| A. Horodysky | 9 mos. | 16,334 | | 16,334 |
| Fringe benefits @ 35% | | 2,389 | | 2,389 |
| | | | | 0 |
| Supplies | | 3,000 | | 3,000 |
| | | | | 0 |
| Travel | | 3,000 | | 3,000 |
| | | | | 0 |
| Vessel Rental | | 500 | | 500 |
| | | | | 0 |
| TOTAL | | 32,048 | | 32,048 |
| | | | | 0 |
| Facilities & Administrative Costs | | 8,012 | 6,185 | 14,196 .6 |
| Total | | 40,060 | 6,185 | 46,244 .6 |

Facilities & Administrative Costs:

The VIMS institutionally approved rate is 45%, however, F&A costs for VMRC requests are limited to 25%.
The remaining costs are contributed as part of VIMS match for this project

Proposal submission to

THE RECREATIONAL FISHING ADVISORY BOARD
VIRGINIA MARINE RESOURCES COMMISSION

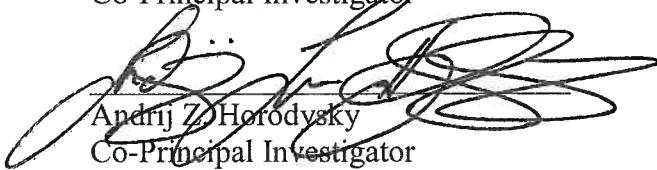
By

THE VIRGINIA INSTITUTE OF MARINE SCIENCE
COLLEGE OF WILLIAM AND MARY

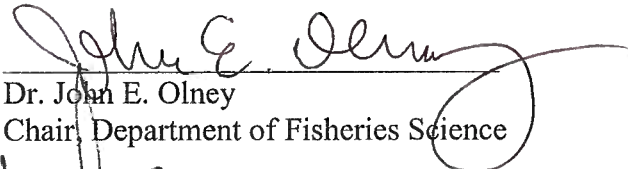
**SEASONAL CALORIC NEEDS AND ENERGY INTAKE OF CHESAPEAKE BAY'S
PREDATORY FISHES: WHICH PREY FUEL GROWTH?**



Dr. Robert J. Latour
Co-Principal Investigator



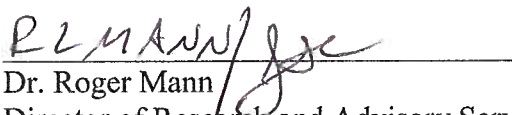
Andriy Z. Horodysky
Co-Principal Investigator



Dr. Joan E. Olney
Chair, Department of Fisheries Science



Jane A. Lopez
Director, Sponsored Programs



Dr. Roger Mann
Director of Research and Advisory Services

June 15, 2008

Background/Need

Tracing energy flow is especially critical in coastal estuarine systems, where the synergistic effects of fishing pressure, anthropogenic stressors, and climatic variation impact population dynamics and trophic interactions of managed fishes and invertebrates (Baird and Ulanowicz, 1989; Cloern, 2001; Latour et al., 2003). Knowing the energy requirements of predatory fishes and caloric values of their prey can greatly enhance the understanding of trophic interactions and energy flow within an ecosystem (Lawson et al., 1998). Modeling of predator growth potential suggests that prey quality and abundance within Chesapeake Bay varies on seasonal and spatial scales (Brandt and Kirsch, 1993), however accurate predator-prey models require a better understanding of predator energetic needs and prey caloric values for the various seasons, ages/sizes, and ecosystems in which predators and prey encounter one another (Hartman and Brandt, 1995).

Surprisingly few direct measurements of metabolism exist for Chesapeake Bay's predatory fishes, and even fewer data are available on the caloric values of prey species (Hartman and Brandt, 1995). As a result, researchers have been forced to assume that caloric values of prey are constant in the absence of alternate data, or use estimates from related or ecologically-similar species (Hartman and Brandt, 1995). However, energetic requirements of predatory fishes and caloric quality of prey may vary dramatically with temperature, season, age/size, geographic distribution, and diet, suggesting this assumption is frequently violated (Brett and Groves, 1979; Tirelli et al., 2006). Further, many predatory fishes increase intake of high calorie prey to prepare for or recover from spawning (Milton et al., 1994), caloric values of some prey are greater than others regardless of taxonomy or ecology (Anthony et al., 2000), and individual prey species are often more energy-rich during their respective spawning seasons than other times of year (Rand et al., 1994; Payne et al., 1999). It is therefore unclear at present which prey species are most critical to fulfill the seasonal energy requirements of Chesapeake Bay's recreationally-important fishes, and which may contribute most to the basic metabolic needs or the energy surplus above maintenance rations that facilitate growth and reproduction. Such data have provided powerful insights into mechanisms mitigating the ecological interactions and dynamics of recreationally important fishes in other ecosystems (Rand et al., 1994).

Identifying the basic energy requirements and mechanisms of energy flow resulting from food web interactions between multispecies predator and prey guilds are critical first steps towards combining ecosystem level processes and population level inferences (Latour et al., 2003). We therefore propose to estimate the seasonal energy intake of striped bass, weakfish, spotted seatrout, red drum, and summer flounder by:

- 1) estimating the seasonal caloric values of their common prey types in Chesapeake Bay via bomb calorimetry
- 2) and combining these data with dietary inferences and metabolic energy requirements from ongoing studies at VIMS and from the literature.

The energy budget of fishes

The energy budget of fishes is given by the bioenergetic equation (Brett and Groves, 1979):

$$\text{Consumption} = \text{Metabolic needs} + \text{Growth} + \text{Reproduction} + \text{Waste} \quad \text{Eq (1)}$$

Energy budgets are end-sum propositions: consumed energy is "taxed" by temperature-dependent metabolic needs (basal metabolism + activity + the costs of protein assimilation) and wastes, and the remaining energy is apportioned to growth and reproduction. Fish basal metabolism depends on water temperature, roughly doubling for every 10°C increase and halving for every 10°C decrease. At 20°C (68F), the average predatory fish requires about twice as much energy to fulfill basic metabolic needs it did at 10°C (50F). Active metabolism in fishes may occasionally double or

triple the basal metabolism, and the cost of protein assimilation of meals may require another 20-30% of the energy budget (Brett and Groves, 1979). Although a gross generalization, combined metabolic requirements may account for ~ 60% of consumed energy in actively foraging fishes, and another ~20% is used for excretion and osmoregulation. Thus a small fraction of consumed energy (~20%) remains for growth and reproduction, placing a premium on quality caloric intake. Three classes of macronutrients provide the caloric value of a food item: carbohydrates (~4 calories per gram), proteins (~4.2 calories per gram), and lipids (~9 calories per gram). Since carbohydrates are fairly uncommon in most aquatic animals, aquatic prey are typically composed of varying ratios of protein and fat (Lawson et al., 2000).

A suite of preconsumptive and postconsumptive factors govern energy acquisition. Preconsumptive factors include the energy associated with chase, capture, manipulation, and mechanical processing, while postconsumptive factors include the energy associated with digestion, assimilation, and gut evacuation (Lankford and Targett, 1997). For a predator, good energetic dietary choices provide high net energy gain: they contain moderate-to-high caloric energy, require little energy to capture, process, digest, and assimilate, and digest rapidly to allow for subsequent feeding. Poor energetic choices provide low net energy gain; they contain low-to-moderate caloric energy, require more energy to capture, process, digest, and assimilate, and digest slowly enough to impede future meals. High calorie prey alone may not be a “good” choice as energy dense meals are often hard and slow to digest, impede the rate of future feeding and bear high metabolic costs of protein assimilation. In fact, an experimental study of weakfish fed two shrimp species demonstrated that those consuming a smaller, lower energy prey item that was easier to capture digested meals more rapidly, fed more frequently, and grew almost twice as fast as those fed a larger, more mobile and energy dense prey item that took longer to digest (Lankford and Targett, 1997). It is therefore likely that at the population level, many other fishes derive substantial nutrition from prey that aren’t the largest and/or most energy dense.

Expected results/benefits

To the scientific community and fisheries management

It is clear that the future state of the Chesapeake Bay ecosystem and its fisheries will be determined by the degree to which management authorities and conservation agencies incorporate the concepts of ecosystem-based fisheries management (EBFM). However, a major hurdle to the successful implementation of EBFM is that the basic data on biomass, trophic interactions, and prey quality required to construct multispecies assessment models are unavailable for many key species that inhabit the bay. The data resulting from this project will fill substantial gaps in the basic scientific knowledge of the energetic needs of managed recreational fishes, and caloric values of their prey. Further, these data will be used in concert with stomach contents studies ongoing at VIMS to examine what prey species are most commonly consumed by predators in each season, and which prey contribute most to the seasonal energy requirements of predatory fishes (metabolism, growth, reproduction). This endeavor has great potential to identify which prey species are most critical (thus potentially in need of management) for population-level growth of recreationally important fishes. Combined, these insights will, for the first time in Chesapeake Bay, place measured seasonal energetic units on the relationships between predators and prey that underlie many ecosystem-based and predator-prey interaction models.

To Virginia’s recreational anglers

This project will provide Virginia’s marine recreational anglers with previously unavailable insights into the energy needs and nutrition of recreationally important sportfishes. The implications include: a better understanding of why/how temperature changes affect the feeding requirements of gamefishes, the relative caloric content of various prey species, how prey caloric values change in time (i.e. during which seasons certain prey are most energetically desirable to predators). Results from this study also have direct implications for optimal lure selection (which prey should we

imitate seasonally from an intake vs/ energy standpoint) and for bait/lure presentation (retrieve speed and dynamics). As we have demonstrated in the past, we consider the dissemination of results to Virginia's recreational anglers to be critical and fully intend to continue this practice with the current proposal.

Approach

Prey energy density

Prey samples have been obtained from 2005-present and will be obtained in 2009 from existing stratified random fishery-independent surveys sampling the Chesapeake Bay mainstem (ChesMMAP) and tributaries (VIMS Juvenile Fish and Blue Crab Trawl Survey). Collections will be pooled into three seasons: spring (Mar-Apr-May), summer (June-July-Aug), and fall (Sept-Oct-Nov). Sample prey organisms (Table 1) will be placed on ice in the field and frozen in water at VIMS to prevent desiccation during storage.

Table 1. Prey items proposed for this study

| Vertebrate prey species | Invertebrate prey species |
|---|---|
| Atlantic menhaden (<i>Brevoortia tyrannus</i>) | Grass shrimp (<i>Palaemonetes</i> spp.) |
| Bay anchovy (<i>Anchoa mitchelli</i>) | Sand shrimp (<i>Crangon septemspinosa</i>) |
| Atlantic croaker (<i>Micropogonias undulatus</i>) | Mantis shrimp (<i>Squilla empusa</i>) |
| Spot (<i>Leiostomus xanthurus</i>) | Blue crab (<i>Callinectes sapidus</i>) |
| Atlantic silverside (<i>Menidia menidia</i>) | Opossum shrimp (<i>Neomysis americana</i>) |
| Mummichog (<i>Fundulus heteroclitus</i>) | Polychaete worms (<i>Nereis</i> and <i>Glycera</i> spp.) |

We will use bomb calorimetry to assess the energy density of prey items; this technique is preferred for whole-animal caloric estimates relative to proximate analysis and wet oxidation (Craig et al., 1978). In the laboratory, whole prey items will be weighed (wet weight), dried at 60 °C, reweighed (dry weight), and homogenized. Generally, two to three 1.0 g subsamples of dried homogenate per prey item will be combusted in a fully automated Parr 6300 isoperibol oxygen bomb calorimeter to determine energy density (KJ g⁻¹). This calorimeter requires samples greater than 0.5 g for accurate combustion, thus smaller prey items (< 0.5 g dry weight) will need to be pooled to form a composite 0.5 g sample. Following combustion, the resulting energy density of composite samples will be divided by the number of individuals in the sample to determine the energetic value of individuals. This methodology is common in studies measuring energy density of small prey (Strange and Pelton, 1987; Lankford and Targett, 1997).

The energy density estimates obtained from individuals of the same species within each collection (trawl) may be regarded as temporally/spatially non-independent. To avoid this potential bias and instead produce independent species-specific collection means, the energy density estimates for each collection of each given species (rather than the individual data) will be averaged. For each species, the mean energy density for each collection will be averaged to produce seasonal energy density means.

Predator energy needs

We will obtain standard and active metabolic rate data for weakfish, spotted seatrout, red drum, summer flounder and striped bass from ongoing VIMS research (A. Horodysky and R. Brill, unpubl.) and from the scientific literature. The effect of mass on metabolic rate is defined by the allometric exponent *b* in equation:

$$MR = a * M^b ; \quad \text{Eq. (2)}$$

where MR is metabolic rate, in mg O₂ kg⁻¹ hr⁻¹ and M is body mass (g or kg). The allometric exponent *b* varies between 0.7 and 0.8 in most fishes (Brett and Groves, 1979).

Standard and active metabolic rates are traditionally reported as milligrams of oxygen consumed per unit time per unit mass. A useful property of metabolic rate data is that they scale

with temperature. In fishes, metabolic data are standardized to a constant temperature via the equation:

$$K_2 = \frac{K_1}{Q_{10}^{1/(10/t_1 - t_2)}}, \text{ where} \quad \text{Eq. (3)}$$

K_2 = the metabolic rate at desired temperature

K_1 = the metabolic rate at recorded temperature

Q_{10} = enzymatic reaction velocity for every 10° change in temperature (~1.65 in fishes, White et al, 2006)

t_1 = recording temperature

t_2 = desired temperature

Seasonal temperature data for Chesapeake Bay will be obtained from the stratified random monitoring surveys (VIMS ChesMMA and Juvenile Trawl). Available metabolic data will be standardized to the seasonal means of these recorded temperatures. Subsequently, these data will be transformed from oxygen consumption to energetic units via the application of an oxycaloric constant of 13.59 J mg⁻¹ O₂ (Elliott and Davison, 1975). This approach allows the expression of metabolic-temperature relationships of oxygen consumption in energetic terms.

Predator Diet

Predator diet data will be obtained from the stratified random VIMS ChesMMA survey, which operates bimonthly from March-Nov, with approximately 80 to 90 sites sampled per cruise within the mainstem of Chesapeake Bay. Since these trawl collections essentially produce a cluster of fish of a given species at each sampling location, the indices will be calculated using a cluster sampling estimator (Buckel et al., 1999). For example, the contribution of each prey type k to the diet by weight (% W_k) will be calculated by:

$$\%W_k = \frac{\sum_{i=1}^n M_i q_{ik}}{\sum_{i=1}^n M_i} * 100 \text{ where, } q_{ik} = \frac{w_{ik}}{W_i} \quad \text{Eq. (4)}$$

and where M_i is the number of predators collected at sampling location i , W_i is the total weight of all prey items encountered in the stomachs of predators collected from sampling location i , and w_{ik} is the total weight of prey type k in these stomachs.

Seasonal population-level consumption ($C_{i,w}$) of specific prey by a specific predator (k) will be calculated as:

$$C_{i,w,k} = D_i \cdot (24 \cdot p_{w,k,i} \cdot \hat{E}) \cdot \hat{N}_i, \quad \text{Eq. (5)}$$

Where D_i is the number of days in season i , 24 is the number of hours in a day, $p_{w,k,i}$ is the mean wet mass of item W in the diet of predator size class k during season i , \hat{E} is an estimate of prey gut evacuation (modeled from the literature), and \hat{N}_i is an estimate of the minimum trawlable abundance of predator k in season I .

Seasonal energy consumption

Seasonal estimates of energy intake by predators will subsequently be obtained using the formula:

$$I_{w,k,i} = C_{i,w,k} * e_{w,i}, \quad \text{Eq. (6)}$$

where $I_{w,k,i}$ is the caloric value of prey w by predator size class k during season i , $C_{w,k,i}$ is the mean wet mass of item w in the diet for each size class k during season I calculated in Eq. 5, and $e_{w,i}$ is the mean mass-specific energy content of prey w during season i (sensu Boyd, 2002).

Prey energy density and predator energy consumption data will be analyzed via the development and selection of a series of generalized linear models (GLMs, McCullagh and Nelder, 1989). GLMs can accommodate non-normal data and are thus applicable to analyze data collected under a variety of designs, including those containing only categorical explanatory variables (ANOVA), those containing only continuous explanatory variables (regression), and those containing both categorical and continuous explanatory variables (ANCOVA). The GLM approach is ideal because these models are both powerful and general. This latter characteristic is key in the context of this project, as it is difficult to know *a priori* the exact structure of the data (and therefore the appropriate statistical design) given the variable nature of trawl catch across seasons and spatial locations. Models will be assessed, ranked, and selected using the information theoretic approach (Burnham and Anderson, 2002) based on the Akaike's information criterion (AIC_c). This approach will assess the strength of evidence for the modes considered and will determine the relative importance of explanatory variables (Burnham and Anderson, 2002).

Estimated cost

We expect the cost of this study to be \$40,060 for one year. We have independently obtained the Parr Calorimeter, grinder, pelletizer, and rinsewater water recirculating system (~\$26,000), storage freezer, high precision scales, major electronic and specialized computer equipment subcomponents required for calorimetry from several sources (~\$10,000). Accordingly, we will not need to ask the RFAB for funds to obtain the expensive equipment necessary to do this work. Additionally, the metabolic rate and predator diet data we will use in this project are from ongoing VIMS research that will come at no cost to RFAB in this proposal.

Requested funds would cover:

- (1) the salary costs of nine months of a VIMS graduate student to conduct this work,
- (2) a research supply/expenditure budget of \$3,000 which would cover calorimeter operation, maintenance, and disposable laboratory supplies (gaskets, standardization tablets, ignition wires, sample dishes, etc.).
- (3) a travel budget of \$3,000 to cover collection and transportation of additional predators and prey from local sources to the VIMS animal holding facilities, mileage for presentations at fishing club and national meetings
- (4) a vessels budget of \$500 for ancillary collections of samples,
- (5) VIMS Facilities & Administrative Costs at the VMRC reduced rate of 25% (the standard institutional rate is 47.45%). VIMS will provide the difference of the reduced rate versus the institutional rate as match funds.

References

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